Research, reviews & patents

Deposition influence on AlN films

Hao Cheng *et al* at the School of Materials Engineering, CPPL Lab, Nanyang Tech. University, Singapore have focused on AlN thin films. With novel thermal properties, chemical stability, high hardness and acoustic velocity and large electromechanical coupling coefficient, as well as a wide band gap, these have received considerable interest as promising candidate electronic material for thermal dissipation, dielectric and passivation layers, surface acoustic wave devices, and photoelectric devices.

Many techniques, such as sputtering CVD, laser CVD, pulsed laser ablation and MBE have been used to prepare AlN thin films on various substrates. In most cases the deposition temperatures are quite high. High temperature deposition has the disadvantage of the degradation of the substrate and the AlN thin films during deposition due to thermal damage. Hence deposition of AlN thin films at low temperatures has become increasingly important and valuable. Sputtering technique is promising under circumstances where low temperature deposition and conformal coatings are needed.

Using a planar magnetron sputtering system for film deposition (supplied by a UK coaxial company) the system consists of a cylinder chamber with two 3" water-cooled target holders tilted at approximately 30° with respect to the normal of the horizontal substrate holder. An impedance-matching network was used to optimise the RF power input. 2×2 cm^2 (1 0 0)±0.5° silicon wafers were used as substrates.

Wurtzite aluminum nitride (2H-AlN) films were deposited on (1 0 0) silicon wafers RF magnetron reactive sputtering under various deposition conditions. The evolution of structure and morphology of AlN films were studied by X-ray diffraction and FESEM.

The preferred orientation was found to be sensitive to deposition conditions such as sputtering pressure, RF power, N2 concentration. Gas flow rate showed no distinct influence on the preferred orientation, but the crystalline quality of the deposited film was improved with the increase of flow rate. Temperature influenced the preferred orientation in a complex way. A correlation between preferred orientation and morphology was observed. It was found that worm-like grains are favourable in films with (1 0 0) preferred orientation. Pebble-like grains are likely to grow in films with (0 0 2) preferred orientation. Pyramid cone structure prevails in films that show the existence of (1 0 1) peaks in XRD spectrum.

Source: *Solid State Sciences* **6** (4) 349-355 (April 2004.)

Proximity-control of SiC etching

Byungwhan Kim *et al*, of Sejong and Chonnam National University, South Korea have been working on SiC.

By controlling its proximity relative to plasma source, silicon carbide (SiC) has been etched in a C2F6 inductively coupled plasma. This was accomplished by adjusting the gap between the wafer substrate and the plasma source.

Gap effects on SiC etching were extensively examined as a function of process factors as well as at particular two conditions, high source power (plasma density) and high bias power (ion bombardment).

Decreasing the gap increased the etch rates for all conditions mainly due to the increased plasma density. The DC bias induced with the gap variation played a little role in affecting the etch rate. Gap effect was more enhanced as the wafer electrode was powered with relatively larger DC bias.

Factor effects on the etch rates were quite different depending on the level of plasma density or ion bombardment. Decreasing the gap resulted in a microtrench at the base of the sidewall, which was little affected by the DC bias. Source: *Thin Solid Films* **434** (1-2) 23 (June 2003.)

SiGe resonance phase transistor

German researchers E Kasper *et al* from the Institut für Halbleitertechnik, the University of Stuttgart, DaimlerChrysler AG, and Max-Planck Institut für Festkörperforschung, Stuttgart, Germany have been working on a SiGe resonance phase transistor: active transistor operation beyond the transit frequency f_T .

For the first time it has been possible to obtain a current gain increase to more than 0dB at frequencies beyond the transit frequency f_T by use of an SiGe resonance phase transistor (RPT). This was achieved by using a very thick base layer with a graded high content Ge profile and a thick low doped collector to get a large phase delay in the carrier drift and a delayed injection. Based on these ideas the so called RPT was fabricated. To get sufficient phase delay in the base, it is necessary to grow very thick base layers (w_B) with graded Ge content (x) up to high Ge concentrations (ie. w_B=120nm, x=5-30%). These structures were grown by MBE at low temperatures in the ultrametastable growth regime. The manufacturing of the transistors was performed by a low temperature process with temperatures below 450°C, using a NiSi/Ag contact metallisation. *Solid-State Electronics* **48** (5) 837-840 (May 2004.)

Inficon control wins patent

Inficon has taken US patent 6700950 for a new method for controlling critical dimension (CD) error in a high part-count, foundry-style semiconductor fab. The method specifically addresses the issue of a fab manufacturing a large mixture of parts under one or more technologies using a common base of equipment, a configuration typical of many semiconductor foundry operations.

The newly patented method is available as an optional add-on module as part of NVS ARGUS Version 2.5.0, a leading commercial APC system for patterning control in microelectronic manufacturing.

"At the 90nm and 65nm production nodes, the ability to control the CD distribution at the lithography step has become the number one correlator to yield and fab productivity. Furthermore, most fabs today are now operating in the 'foundry-style high-part-count' regime, where product mixes are highly diversified and production runs are short and irregular," says Joseph Pellegrini, director, technology & marketing for Inficon Patterning Solutions.

"We demonstrated this new APC method will produce a 10%-20% reduction in CD distribution versus all known competitive methods for run-to-run CD control. That extra 10%-20% in process latitude could be the difference between profitable and unprofitable operation for many fabs," he adds. Results based upon fab data using the new method were published at MNC CD Control seminar in Tokyo, Japan in October last year.

A majority of non-foundry fabs also operate under high-part-count configuration and the percentage is increasing monotonically as the industry consolidates, pushing individual fabs to diversify to remain competitive. In addition to substantially improved CD control, end users benefit by having more wafers qualifying to run under APC control instead of manual control, yielding higher throughput.

Schottky and spin-LED structures

The team of J F Bobo *et al* from CNRS, Toulouse, France have worked on a Comparative *I(V)* study of pure Schottky contacts used in spin-LEDs and present the analysis of the results of *I(V)* characteristics of n-GaAs/Co Schottky structures and of spin-LED structures of the type [p-GaAs/p-AlGaAs/AlGaAs/GaAs/AlGaAs/n-AlGaAs]/Co where the semiconductor heterostructure acts as a quantum well LED.

They have focused this study on tunnelling through the space charge layer at the metal-semiconductor interface, and report strong differences for the *I(V)* characteristics of the two structures, which can have important implications in the understanding of the exact mechanism of spin injection between a metal and a semiconductor.

The team has proposed a method for detecting the presence of a space charge layer at the metal-semiconductor interface in semiconductor/ferromagnetic metal junctions for spin electronics devices.

This space charge is sometimes supposed to exist, but was never tested in such structures. It is based on the observation and modelling of the limitation of the forward current in spin-LEDs by the blocking effect of the Schottky diode.

They report the absence of this effect in functional spin-LED structures and the researchers explained this feature by the fact that n-GaAs layer forming the Schottky barrier is too thin to realise the space charge layer (nominal thickness of n-doped layer=500 Å in our case).

The method presented here appears to be appropriate to evidence the eventual existence of this space charge and, if it is the case, control the thermoionic field emission mechanism (TFE) in the reverse mode of Schottky junctions. They have shown that this mechanism contributes to tunneling in N/FM structures and has to be accounted for. In the case of spin-LEDs based on Schottky barriers, and if it were proved that the interfacial resistance is necessary, an improved control of TFE is expected to optimize spin injection efficiencies up to room temperature and above. Thus, systematic *I(V)* controls in this sense should be of uppermost interest associated with electroluminescence analysis of circular light polarizations when characterising spin-LEDs.

Source: *Solid-State Electronics* **48** (5) May 2004.

Decade's work in *Toolkit for Evaluating Public R&D Funding*

It's hard to measure innovation. Public support for R&D has long been recognised as an important tool for enhancing economic growth, but determining which programmes are most effective has been problematic for just as long. The Advanced Technology Program (ATP) at the National Institute of Standards and Technology (NIST) has more than 14 years of experience evaluating R&D and been recognised by the National Research Council for setting "a high standard for assessment."

Using a variety of research tools, including surveys, econometric models, detailed case studies and literature analysis, ATP economists have assembled a significant body of research and data on the innovation process and contributed to the development of the academic theory on assessing R&D programs.

The new ATP publication, *A Toolkit for Evaluating Public R&D Investment*, assembles in one volume a decade's worth of ATP experience in the measurement of innovation.

This includes a general framework for evaluation, a discussion of an evaluation logic model, fundamentals and methods, demonstrations of the ATP's use of evaluation methods, and a summary of an emerging body of knowledge from ATP studies.

These cover firm behaviour, collaboration, spill over effects, interfaces with state and international technology programmes, as well as the overall performance of the programme. It also includes a glossary of terms, methods bibliography and a quick reference guide to evaluation models and methods.

Single copies of *The Toolkit* are available by writing the Economic Assessment Office, Advanced Technology Program, NIST, 100 Bureau Drive, Mail Stop 4710, Gaithersburg, MD 20899-4710, or e-mail:atp-eao@nist.gov. Web: www.atp.nist.gov/eao/gcr03-857/contents.htm

Sol-gel fabricated and patterned phosphor films

X. M. Han et al of the Key Laboratory of Rare Earth Chemistry and Physics, and the Changchun Institute of Applied Chemistry, China have been working on phosphor films and patterning by a sol-gel process. X2-Y2SiO5:A (A=Eu3+, Tb3+, Ce3+) phosphor films and their patterning were fabricated by a sol-gel process combined with a soft lithography. X-ray diffraction (XRD), FT-IR, AFM, SEM, optical microscopy and photoluminescence (PL) were used to characterise the resulting films.

The results of XRD indicated that the films began to crystallize at 900 °C with X1-Y2SiO5, which transformed completely to X2-Y2SiO5 at 1250°C. Patterned thin films with different bandwidths (5m spaced by 5 m and 16m spaced by 24m) were obtained by soft lithography technique (micromoulding in capillaries, MIMIC).

The SEM and AFM study revealed that non-patterned phosphor films were uniform and crack free, and the films mainly consisted of closely packed grains with an average size of 350 nm. Rare earth ions Eu3+, Tb3+ and Ce3+ show strong emission with red (613 nm, 5D0-7F2), green (542nm, 5D4-7F5) and blue (350-450 nm). The optimum concentrations for the luminescence of Eu3+, Tb3+ were determined to be 13 and 8 mol% of Y3+ in X2-Y2SiO5 films, respectively.
The current methods for the preparation and patterning of phosphor films can be extended to other phosphor films and have potential application for the fabrication of optical devices.